

Physical capacity in physically active and non-active adolescents

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Postprint / Postprint

Zeitschriftenartikel / journal article

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Empfohlene Zitierung / Suggested Citation:

Mikaelsson, K., Eliasson, K., Lysholm, J., Nyberg, L., & Michaelson, P. (2010). Physical capacity in physically active and non-active adolescents. *Journal of Public Health*, 19(2), 131-138. <https://doi.org/10.1007/s10389-010-0371-5>

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PHYSICAL CAPACITY IN PHYSICALLY ACTIVE AND NON-ACTIVE ADOLESCENTS

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**PHYSICAL CAPACITY IN PHYSICALLY ACTIVE
AND NON-ACTIVE ADOLESCENTS**

ABSTRACT

Aim: The aim of this study was to investigate differences in physical capacity between physically active and non-active males and females among graduates from upper secondary school. **Subjects and methods:** Research participants were graduates, (38 female and 61 male) from upper secondary school. Physical activity was determined using International Physical Activity Questionnaire and participants were dichotomously characterized as being physically active or physically non-active according to the recommendations of the World Health Organization (WHO). Aerobic capacity was measured using the Åstrand cycle ergometry test. Participants also underwent tests of muscular strength and balance. **Results:** Maximum oxygen uptake differed significantly between physically active and non-active males (mean \pm SD: 3.6 ± 0.7 vs. 3.0 ± 0.6 l/kg, $p = 0.002$) and females (3.0 ± 0.6 vs. 2.5 ± 0.3 l/kg, $p = 0.016$). There was a difference among physically active and non-active males regarding push-ups (37.1 ± 9.0 vs. 28.5 ± 7.0 , $p < 0.001$) and sit-ups (59.2 ± 30.2 vs. 39.6 ± 19.4 , $p = 0.010$). No significant differences were found regarding vertical jump or grip strength among males, any of the muscle strength measurements among females, and balance (in any sex). **Conclusion:** Activity levels had impact on aerobic capacity in both sexes, but did not seem to have the same impact on muscular strength and balance, especially in females.

Key words: adolescents, balance, cardiovascular capacity, muscular capacity, physical activity.

Physical activity contributes to several positive effects on physical capacity and both physical and mental health (Blair et al. 2001; Hallal et al. 2006). For children and young people, all types of physical activity and exercise are essential to create conditions for the body to adapt and to cope with both current and future physical and mental demands and are therefore important properties for children's physical, mental and social development (Malina 1994). This is one reason why physical education and health are part of the core curriculum for all programs in the Swedish upper secondary school. Due to this, Swedish adolescents would not be likely to be completely physically non-active; nevertheless several of them are less active than what is considered to be necessary to maintain good health (Swedish National Institute of Public Health 2009).

The three main health components of physical capacity are: cardio-respiratory capacity, muscular capacity and mobility (Ortega et al. 2008). Between 18 and 20 years of age, the cardio-respiratory capacity peaks in both sexes (Rogol et al. 2000; Rutenfranz et al. 1982; Wilmore 2000; Zaichkowsky 1995; Åstrand 1997). The development of muscle mass occurs mainly during puberty, but between the ages of 20 to 30 years the maximum muscle strength in men increases, while women's growth is less (Åstrand 1997).

Most studies show that the degree of physical activity has decreased among Swedish children and adolescents over the past decades and that the number of sedentary young people has increased (Bratteby et al. 1997; Ekblom et al. 2004; Engström 2004). As physical activity has decreased, physical capacity has shown similar pattern (Ekblom et al. 2004; Westerstahl et al. 2003). Ekblom et al (2004) present how the physical capacity changed between 1987 and 2001 for children of ages of 10, 13 and 16 years. The study showed a significant reduction in the cardio-respiratory capacity of 16-years old boys from 1987 to 2001, while it remained unchanged in girls. The study also showed that the muscular capacity was reduced in 2001 as compared to 1987 in both sexes (Ekblom et al. 2004). Malina (2001) has shown that children and adolescents who are physically inactive will remain inactive as adults. This is in many ways alarming, as physical inactivity as well as impaired cardiovascular and muscular capacity has a strong relationship with most health related problems (Pate et al. 2009; Pedersen et al. 2006).

Many countries have adapted guidelines for physical activity. The recommendation of Swedish Institute for Public Health is: "All individuals should, preferably every day, be

physically active for a total of at least 30 minutes. The intensity should be at least moderate, such as brisk walking. Additional health effect can be obtained if in addition you increase the daily volume or intensity" (Swedish National Institute of Public Health 2009). Sweden and other Nordic countries have a common recommendation for children and young people of at least 60 minutes of physical activity per day and that activity should include both moderate and high intensity (Swedish National Institute of Public Health 2009). This is consistent with the World Health Organization (WHO) recommendations for children, which reads: "Each day school-aged youth should accumulate at least 60 minutes of moderate-to vigorous-intensity physical activity to ensure healthy development. This can provide young people with important physical, mental and social health benefits." (Strong et al. 2005; World Health Organisation 2009). In a large Swedish study the physical activity habits of 14 to 15 year old adolescents in the Stockholm region 2000-2001 were examined. The study showed that 71% of young people met with the recommendations regarding 60 minutes of daily physical activity. There was an obvious sex difference; more girls than boys did not reach the recommended level (Rasmussen and Eriksson 2004). Other studies have also shown that girls are less physically active (Pate et al. 2002; Sallis et al. 2000).

Previous studies regarding physical activity and its relation to physical capacity were targeted at either children, young people of 15-16 years of age, or adults. To our knowledge, there are no studies regarding physical capacity in the last year in the upper secondary school (i.e. 18 years old) and as oxygen uptake peaks at this age it would be of great interest to examine potential differences in capacity between active and non-active individuals. Also, this age group is about to leave school and move into adulthood. Research has shown that the level of physical activity decreases after high school, particularly among females (Nelson et al. 2006). Altogether, this age-group is at a turning point in life. Previous research have shown a tendency to a reduced physical activity which reinforces the individual's habits of inactivity and therefore contributes to a subsequent physical inactivity (Malina 2001).

The aim of this study was to investigate differences in physical capacity in physically active and non-active males and females among graduates of upper secondary school.

METHODS

Participants

Participants were recruited on two different occasions. In total, 99 persons participated, of which 38 were females and 61 were males. All participants were between 18-20 years old.

In the first test occasion participants were recruited through a questionnaire survey on physical activity among third grade students from upper secondary school in three different municipalities Boden (Björknäs), Luleå (Luleå gymnasieby) and Piteå (Strömbacka) (results not yet published). Each participant of the questionnaire survey was also asked whether they were interested to participate in a forthcoming study of either physical capacity and/or interview as part of a larger data collection. In total 62 adolescents accepted to participate, out of 884 who answered the questionnaire. These 62 adolescents conducted the tests of physical capacity during spring 2007 in three different cities in northern Sweden.

After the first data collection, there was a skewed distribution of participants in the study, with the majority being physically active. So, to obtain more equal group sizes of physically active and non-active a second round of data collection was conducted. The recruitment of participants for the second data collection took place at one of the upper secondary school involved in the first data collection, Björknäs school at Boden. Students in grade three of the vocational programs were personally asked if they wanted to participate in a study of physical capacity. The reason for the choice of the vocational programs was that studies have shown that more students at these programs are physically non-active compared to those participating in the more theoretical programs (Sollerhed 1999; Westerstahl et al. 2005). A total number of 143 students were invited to participate and 37 agreed. All of them performed their testing within the next few days.

Assessments

The physical tests were selected in order to provide reliable and valid measures of the aerobic capacity, the muscular strength of the upper and lower body and balance. The test battery has previously been used in studies with similar aims, designs and study population (Ekblom et al.

2007; Ekblom et al. 2005; Westerstahl et al. 2003). The tests were easy to perform without demanding technical equipment, making them advantageous to use and easy to replicate in clinical practice.

Physical activity

Physical activity was determined using the responses of the International Physical Activity Questionnaire (IPAQ) short form (International Physical Activity Questionnaire 2007) IPAQ has been tested for validity and reliability in adults and adolescents (Craig et al. 2003). A small modification was made for the purpose of this study, whereas respondents were asked to rate their usual activity during an ordinary week in the past six month, instead of just the last seven days. This was made because we wanted to describe activity habits rather than the most recent activity performance, and because of the sensitivity of the relatively small study sample for temporary variations due to sickness and other aleatoric reasons.

Based on responses regarding physical activity on the IPAQ's vigorous and moderate levels, participants were characterised dichotomously as physically active or non-active. To be characterised as physically active, a respondent should have reached the WHO recommendation of physical activity for adolescents (World Health Organisation 2009) at least a total of 60 minutes per day and 7 days per week. Of the 38 females, 22 (58 %) were characterised as physically active and 16 (42 %) as non-active. Among the 61 males, there were 40 (66 %) physical active and 21 (34 %) physically non-active, adding up to 99 participants.

Anthropometric measurement

Prior to the physical testing, the participants' height and weight were measured. Height was measured with the participant standing against the wall using a Stadio meter (Seca GmbH & Co.Ka. Germany). The weight in kilograms to the nearest decimal was measured on a digital scale (Seca GmbH & Co.Ka. Germany). During the entire test procedure the participants were wearing light workout clothes and were barefooted. Height, weight and Body Mass Index (BMI)(Cole et al. 2000) are presented in Table 1.

Insert Table 1 about here

Aerobic capacity

The aerobic capacity was determined by a sub maximal cycle ergometer test (Åstrand, 1997) performed on Monark Ergomedic 826E. Prior to the beginning of test, the bicycles were calibrated. Cadence was set to 50 rpm, guided by a metronome during the test. Heart rate was registered with the Polar heart rate watch (Polar Electro Oy, Kempele, Finland). The participants pulse was recorded every minute as well as their respiratory effort, and their perceived effort in the legs using the BORG scale (Borg 1982). The achieved steady state pulse rate at the given workload at the end of the test was converted to the oxygen consumption using Åstrands - Ryming monogram (Åstrand 1997).

Upper extremity muscle strength

Muscle strength of the upper extremity was assessed using push-ups and grip strength.

Push-ups are a test recommended as a reliable method for measurement of muscle strength in the arms (Ryman Augustsson et al. 2008). In order to standardize the “push-ups”, the hands were placed on a line with an optional distance between the hands. The depth of the push-ups was controlled by a 15 cm cone placed under the sternum, and which had to be touched during the trial for the push-up to be counted as correctly performed. The frequency of push-ups was 30 beats per minute, which was guided by a metronome. The numbers of correctly performed push ups was then noted. Either three incorrectly carried out push ups or exhaustion terminated the test.

Hand grip strength was measured with a grip dynamometer, Grip D, UH 5401 Eleiko Sport (Takei & Co LTS, Tokyo, Japan). The method of measurement is tested for reliability (Watanabe et al. 2005). Before the test, the size of the grip was adjusted in accordance with the size of participants' hand. The test was carried out with the participant standing with the arm hanging alongside holding the dynamometer in the hand. Three trials were performed for

each hand, switching between hands for each trial and the best value for each hand was recorded. A mean value was calculated from the best value from the left and right hand and used in the data analyses.

Lower extremity muscle strength

The strength of lower extremity was measured with a vertical jump. The participants were instructed to jump as high as possible with a plyometric flexion of the hip and knee downwards, followed by an extension of the hip and knee and a simultaneous flexion of the shoulders while performing the jump. The landing, to be counted as a correct jump, should be performed with stretched wrists followed by a bending of the knees inside a 150 cm box outlined on the floor. Three correct jumps were performed of which the best result was used in data analyses. To determine the height of the jump a micro Musclelab Power + was used, which measures time spent in the air that is converted to jump height in centimetres. The method has been tested for validity and reliability (Markovic et al. 2004; Suni et al. 1996).

Trunk muscle strength

The strength of the trunk muscles was measured by the participants performing sit-ups lying on a mat with knees and hips flexed at a 90 degrees angle with the lower parts of the legs resting on a psoas pad. The arms were crossed over the chest with each hand resting on the opposite shoulder. The accepted height of each sit-up was determined in relation to the height of each participant as follows: Stature \leq 160 cm had to lift enough for a line at 45 - centimetre distance from the buttocks to become visible, length \leq 175 cm to a 50 cm marker, length \leq 190 cm to a 55 cm marker and length $>$ 190 cm to a 60-cm marker. The sit-ups were conducted at a rate of 50 beats per minute, guided by a metronome. The test leader counted the numbers of correct sit-ups with a hand calculator. After three incorrectly performed sit-ups the test was terminated. Reliability of the test has been demonstrated (Ryman Augustsson et al. 2008).

Balance

The test for balance was performed by letting the participant stand barefooted with one foot at a time on a 3 cm wide, 5 cm high and 20 cm long list for one minute. Each time the participants lost their balance, and touched the ground with (usually) the other foot, the attempt was registered as unsuccessful. The total number of unsuccessful attempts during one minute was recorded, and the mean number between the right and the left foot was calculated and used in the data analyses. This balance test has been tested for reliability (Tsigilis et al. 2002).

Procedure

All measurements were performed following strict protocols at three different test sites. First, body height and weight were measured. After that the physical tests were made in the following order: Åstrands cycle ergometer test, push-ups, vertical jump, sit-ups, grip strength and balance. In between the tests the participants completed a survey about their physical activity habits (IPAQ). Three assessors were involved in each participant's test session. One performed the cycle ergometer test while the other two performed the physical tests, in order to achieve a correct test procedure and quantification of the performance while simultaneously encouraging the participant. One of the assessors took part in all test sessions. In order to avoid that the participants feeling uncomfortable, test situations were adapted so that the performance could only be observed by the assessors involved. Participants were dressed in comfortable wear of their own choice. Altogether the test session took about 60 minutes for each participant.

Data analyses

Data processing was done using Statistical Package for Social Science (SPSS) version 17.0. As there are substantial differences in physical capacity between males and females (Ortega et al. 2008; Rogol et al. 2000; Viljanen et al. 1991; Åstrand, 1997) the analyses were performed separately. By use of box plot analyses, extreme outliers (defined as values exceeding the distance between median and quartile values more than three times) were identified and

excluded from further analyses. This happened only for the sit-ups performance of one female. By the use of the Student's independent sample t-test, hypotheses regarding differences in aerobic capacity, push-ups, grip strength, vertical jump, sit-ups and balance between those classified as physically active or non-active were tested, separately for females and males. Levene's test for equality of variances (SPSS v. 17) was used to decide the proper t-test algorithm for each analysis. A p-value lower than 0.05 was considered as indicating statistical significance.

Ethical approval

The study is approved by the Regional Ethical Review Board in Umeå, Sweden (3202/2006).

RESULTS

The results from the tests of physical capacity for the physically active and non-active females and males are presented separately in Tables 2 and 3. In some cases data were missing for particular tests because of occasional physical symptoms such as neck pain and ankle strains.

Aerobic capacity differed significantly between physically active and non-active participants in both sexes with a difference of 20 % for both males ($p = 0.002$) and females ($p = 0.016$) (Tables 2 and 3). Regarding strength measures, the numbers of push ups showed a significant difference ($p < 0.001$) for males, with the physically active males performing 30 % more push ups compared to the physically non-active males (Table 3). Also for sit-ups, there was a significant difference ($p = 0.01$) between the active and non-active males (a 49 % difference) (Table 3). No other statistically significant differences were found between the physically active and non-active males or females. The performance in the balance test did not differ significantly between the active and non-active of either of the sexes. Among the males, there was a non-significant tendency ($p = 0.08$) towards a lower capacity among the more active participants.

Insert Tables 2 about here

Insert Tables 3 about here

DISCUSSION

The result showed significant differences between physically active and non-active male and female adolescents regarding aerobic capacity. The activity level did not seem to have strong association with muscular fitness and not at all with balance. Among males, performance in push-ups and sit-ups were better for the active students, something which was not seen among the females.

Concerning adults, knowledge about relationship between health's related outcomes as aerobic capacities and physical activity is immense for example (Hasselstrom 2002; U.S Department of Health and Human services 1996), yet as to our knowledge, the literature is sparsely regarding studies on adolescents on the brink of adulthood. As knowledge is lacking, we consider that our findings that physically non-active young male and females have significant lower aerobic capacity should be valued as important. The adolescents at this age are about to leave school, and their physical activity level will no longer be supported by regular physical education, but only dependent on their own choices. Children and adolescents who are physically non-active tend to remain so as adults (Malina 1996; Ruiz 2007). Furthermore, aerobic capacity in children and adolescents appear to be linked to the cardio respiratory profile later in life (Mesa et al. 2006; Ruiz 2007) and a low aerobic capacity in late adolescence is associated with increased risk of cardiovascular disease later on (Hagstromer et al. 2008; Twisk et al. 2002).

Compared to the difference in aerobic capacity related to activity, the relation between muscle strength and activity is more unclear and in some cases contradictory. Besides the results for push-ups and sit-ups among the males, which were significantly better for the active students compared to the non-active ones, no significant differences were found for all the other strength tests. Viljanen et al (1991) found a difference in vertical jump related to activity; however, this was studied in an older and more non-active population (Viljanen et al. 1991). Traditionally, there has been a conservative attitude against introducing strength training for children and young adolescents. However, there is no evidence supporting such a cautious attitude. Rians et al (1987) conducted a study, which specifically examined possible risks associated with strength training in children. The results showed no adverse effect on any of the investigated parameters (damage to bones, muscles, possible impact on growth, mobility and motor function). The authors concluded that the risk of injury with strength training is

non-existent if it is carried out correctly. On the contrary, there is much support for positive effects from muscle strength training for children and adolescents regarding, for instance, sports injury prevention (Abernethy et al. 2007), motor learning (Falk et al. 1996) bone mineralization (Wang 2007) and obesity and body composition (Benson et al. 2008).

There were no significant differences in the balance test between the active and non-active groups. In fact, there was even a tendency for the active males to have poorer results than the non-active ones. The results are inconsistent with a study by Oddsson and Ekblom (2004) who found a positive association between performance in a balance test and activity level.

The lack of differences between active and non-active students in the majority of the strength and balance tests may theoretically be due to the fact that the test activities were not sufficiently challenging for strength and balance in these age groups. However, most of these tests or similar ones have been used in other studies including similar groups of test persons (Ekblom et al. 2007; Westerstahl et al. 2003). Many of the tests are included in the Eurofit battery of physical tests (Adam et al., 1988). Moreover, they are easy to perform without demanding technical equipment. Another possibility is that the size of the cohort was too small to obtain statistical power for all the test activities.

The recruitment of participants for this study was performed simultaneously as the participants filled in a questionnaire regarding physical activity habits (results not yet published). Retrospectively, we acknowledge the fact that this design of recruitment was not the most efficient way as the response rate was low. The question of participation in future studies was one of many items in the questionnaire, and a more specific recruitment procedure would have been more appropriate. A major concern during data collection was a skewing of the sample with respect to that only physical active adolescent volunteered to participate, which was the case after the initial data collection. So, despite of the methodological problem with an additional sampling of participants, to achieve a fairly representative group of upper secondary school graduates, students at programs known to be less physically active (Sollerhed 1999; Westerstahl et al. 2005) were specially invited for the second round of data collection. This resulted in a more even distribution of physically active and non-active adolescents.

Concerning the estimate of amount of physical activity, which was derived from the IPAQ questionnaire, studies have shown that IPAQ can overestimate self-reported time spent in physical activity (Ekelund et al. 2006). This could potentially bias the categorisation, overestimating the percentage of physically active participants. When interpreting the results, however, it seems that we have achieved a valid categorisation of physically active and inactive participants, since there were statistically significant differences in measures most likely to be influenced by physical activity. Our modification of the IPAQ, asking the respondent to refer to a usual week instead of the last seven days was made because of the relatively small sample where reference to the last seven days would imply a greater sensitivity to temporary activity restrictions due to for example temporary sickness, injuries or examination in school, as pointed out by participants in a larger questionnaire survey (results not yet published).

Regarding the classification of participants as active and non-active, WHO recommendations for physical activity both for adults (from age 19 and up) as well as for children and young people (up to age 18), might apply to our sample (World Health Organisation 2009). We chose to use the recommendation for children and young people since 72% of participants were 18 years old, and as the aim was to study graduates from upper secondary school, which implies that they have not adapted to adulthood. The WHO recommendation for amount of physical activity as health promoting factor are widely spread and acknowledge in modern societies. For that reason it seemed natural to choose this recommendation when classifying participants as physically active or not.

Based on comparisons regarding body height and weight data from the Swedish National Service Administration (2007), the males in our study did not differ from the national population at the same age. The females however were significantly shorter and lighter (Swedish National Service Administration 2007). Aerobic capacity test values were compared with population data from LIV 90 (national sampling of physical capacity, physical activity and health) (Engström et al. 1993). This revealed that the males in our sample did not differ from a male population aged 20-24; however, the females had significantly higher aerobic capacity. Compared with data from studies performed on 16 year old adolescents in the Stockholm area (Ekblom et al. 2005; Westerstahl et al. 2003), the participants in our study seemed to fit in quite well. Regarding grip strength, vertical jump, and balance, the 95% confidence intervals of test results in our study enclosed the reported mean values of the

studies mentioned above. Also in this comparison, the females seemed to have a higher aerobic capacity, while the males seemed comparable (Ekblom et al. 2005). Altogether, it appears that the female participants of our sample were somewhat more fit regarding aerobic capacity than what could be expected from a national population, while the male were representative.

Important reliability aspects of this study are that all test procedures followed a strict protocol and that test leaders were careful to try to give the same verbal encouragement to all participants. It has been shown that the way encouragement is given to the participant influences his or her test performance (Andersson et al. 2004). Further, the test leaders were unaware of which activity group the participants belonged to.

In conclusion, aerobic capacity differed significantly between physically active and non-active males and females among upper secondary school graduates. The activity level did not seem have the same association with muscular fitness and not at all with balance.

The results of the study emphasize the promotion of physical activity in childhood and adolescence, as there are links between both activity and aerobic capacity in adolescence and later life, and in addition to health. The differences in aerobic capacity and some of the strength tests between active and non-active students are not negligible, but are likely to influence the future physical capacity and level of activity. For further research, the relation between muscle strength and different forms of physical activity, especially in females, should be assessed in more well-powered studies. It would also be of importance to establish health-related threshold values for muscular strength and balance.

ACKNOWLEDGEMENTS

We thank the participants for taking part in this study. We will also thank Winternet in Boden, and Step In in Piteå, Sweden, for providing us with staff and test facilities. Financial support was provided from the Department of Health Science, Luleå University of Technology, and the Swedish National Centre for Research in Sports CIF 30/05.

CONFLICT OF INTEREST

The authors declare that they have no conflict interest.

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Table 1. Gender, activity level, height, body weight and BMI reported by mean (m), standard deviation (SD) and min-max values.

	Female				Male			
	Active (n = 22)		Non-active (n = 16)		Active (n = 40)		Non-active (n = 21)	
	Mean (SD)	Min-max	Mean (SD)	Min-max	Mean (SD)	Min-max	Mean (SD)	Min-max
Height (cm)	166 (4.8)	155-173	165 (5.2)	156-174	180 (6.6)	165-193	180 (6.3)	169-191
Weight (kg)	60.5 (6.0)	50-76	59 (9.4)	46-90	77 (10.3)	54-103	76 (14.4)	57-114
BMI (kgxm⁻²)	22 (2.0)	18-25	22 (3.4)	19-33	23 (2.5)	19-29	24 (5.1)	19-38

Table 2. Differences between physically active and physically non-active females aged 18-20 in aerobic capacity, muscle strength and balance.

	Active (n = 22)			Non-active (n = 16)			p
	n	Mean (SD)	Min - max	n	Mean (SD)	Min - max	
Aerobic capacity (l/min)	22	3.0 (0.6)	1.7 - 4.2	16	2.5 (0.3)	2.0 - 3.3	0.016
Push-ups (no.)	22	21.4 (12.0)	0 - 49	16	15.4 (11.8)	2 - 35	0.131
Grip strength (kg)	22	30.0 (4.7)	21.1 - 40.9	16	29.2 (3.0)	22.1 - 33.4	0.505
Vertical jump (cm)	20	28.9 (5.6)	15 - 37	15	28.3 (5.5)	20 - 39	0.757
Sit-ups (no.)	21	41.7 (23.5)	0 - 96	16	44.8 (23.9)	0 - 98	0.696
Balance (no. of failures)	22	4.3 (3.6)	0 - 14	16	5.0 (3.4)	0 - 13	0.559

Table 3. Differences between physically active and physically non-active males aged 18-20 in aerobic capacity, muscle strength and balance.

	Active (n=40)			Non-active (n=21)			p
	n	Mean (SD)	Min - max	n	Mean (SD)	Min - max	
Aerobic capacity (l/min)	40	3.6 (0.7)	2.2 – 5.0	20	3.0 (0.6)	2.0 - 4.3	0.002
Push-ups (no.)	40	37.1 (9.0)	20 - 60	20	28.5 (7.0)	14 - 39	0.000
Grip strength (kg)	40	47.8 (7.5)	33.4 - 66.4	21	48.9 (5.7)	39.6 - 65.6	0.539
Vertical jump (cm)	37	42.4 (5.5)	32 - 55	21	40.9 (7.5)	19 - 54	0.374
Sit-ups (no.)	35	59.2 (30.2)	23 - 136	21	39.6 (19.4)	15 - 88	0.010
Balance (no. of failures)	40	4.4 (3.9)	0 - 16.5	21	2.8 (2.5)	0 - 8	0.080